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THE

# CURIOSITIES OF INDUSTRY.

BY GEORGE DODD,

AUTHOR OF "DAYS AT THE FACTORIES."

## THE CHEMISTRY OF MANUFACTURES.

No. 15.] [Sixpence.

ON THE APPLIED SCIENCES.

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LONDON:
GEORGE ROUTLEDGE AND CO.,
FARRINGDON STREET.
1853.

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# PREFACE.

A FEW words will explain the object of the present series.

It is not intended to treat systematically of the relations which are borne by Manufacturing Industry to Natural Productions, to Mechanical and Chemical Science, to the Fine Arts, to Commercial and International Tariffs, or to Social and Co-operative Arrangements. Nor is it intended to describe in technical form the processes and the localities of our great departments of manufacture. The author of this series gave a popular view of those processes and the localities in a series of "Supplements," to the *Penny Magazine*, a few years since; the substance of which was afterwards embodied in six small volumes, under the title of *British Manufactures*.

The title, "Curiosities of Industry," will pretty clearly explain itself. Many processes are curious without being novel; many are both novel and curious; many reveal to us the store of strange and valuable things which science presents to those who know how to apply it in aid of industry; many arise out of the discovery of new materials; and many more by new applications of old materials. Of all such are these "Curiosities" composed.

Each number is complete in itself.

G. D.

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# THE CHEMISTRY OF MANUFACTURES.

It is difficult to say whether productive industry is more indebted to mechanical skill or to chemistry for its recent astonishing advance. Indeed this may be an insoluble problem: for almost every mechanical process requires the aid of chemistry in its development; while chemistry would be nothing without the aid of the machines, the furnaces, and the vessels which permit the processes to be carried on. What we have to do is, to estimate properly both these invaluable assistants to our industry, without establishing a rivalry between them.

The 'curiosities' of chemistry, in its application to manufactures, are many and varied; and we will attempt a brief notice of some of them.

## The Chemistry of Metal-Working.

Let us begin with a few miscellaneous facts relating to metals—those remarkable material products without which man could never have risen far above the level of the brutes, even if existence itself were possible.

The chemistry of the lead-works is often very interesting, and, in some cases, really beautiful. The metal is mostly obtained in this country by operating upon galena or sulphuret of lead, a hard grayish substance found in considerable quantity in Derbyshire, Northumberland, and other counties. The problem here is, how to get rid of the sulphur which forms one component of the galena; and it is found that the best way to effect this is to give a dose of oxygen by some means, so that the union of the sulphur with the oxygen may carry off both in the form of sulphurous acid gas. The galena is roasted in a furnace, under circumstances which produce this result, and the lead is separated in a metallic form. But some of the highly heated lead goes off in the state of vapour, and a sad perplexity this is to the smelter; for lead-fumes are so deadly poisonous that he tries all practicable means to catch the vapour before it flies off into the atmosphere, and re-transform it into the solid state. These processes are not particularly remarkable; but another, which generally follows, is much more so. Nearly all lead ore contains a little silver, and it is usually worth while to incur the trouble and expense of extracting this silver. When the metallic lead has been prepared from the galena, if it is found to contain even so minute a quantity as five ounces of silver to a ton of lead, it is deemed worth while to subject it to a refining process, for the sake of the silver. The lead of the Northumberland and Cumberland district averages about ten ounces of silver to the ton; and it will therefore warrant the adoption of this process, where operations are conducted on a large scale; some specimens give as high a ratio as a hundred ounces. The pigs of lead are slowly melted in huge iron



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vessels, the molten metal being kept stirred. Portions of the lead crystallise while cooling, fall to the bottom, and are removed by a perforated ladle: and as these crystals contain less silver than the remaining uncrystallised portion, their removal leaves the molten mass richer than before. So matters go on, re-melting and re-crystallising, until perhaps one-twentieth part of the lead contains the whole of the silver. This reduced portion is then exposed to the intense heat of a cupel furnace; the lead combines with oxygen to form litharge, and the silver is separated in a beautiful brilliant cake. Some of the wealthy owners of lead-mines have had costly and magnificent services of plate manufactured from silver obtained wholly by refining the lead.

Copper, again, has its curiosities of manufacture. Nearly all the copper ore that is raised in England, or brought to England, is smelted in South Wales; yet scarcely a particle of this ore is found in that region. Commercial reasons alone have determined the singular location; South Wales can send coal for the steam-engines of Cornwall, and Cornwall can send back copper ore to be smelted in South Wales. The Swansea district now smelts something near 200,000 tons of copper ore yearly, from which about 20,000 tons of pure copper result, worth a million and a half sterling. About ten or a dozen great firms monopolise the whole of this trade. The smelters are not employed by the mine owners to smelt the ore; they purchase it on speculation, smelt it, and then find a market for the metallic copper. The sellers and the buyers form a snug little sort of family party, which meets once a fortnight in a hotel at Swansea; they all know each other, and every firm is fully cognizant of the purchases made by the others. The sale is not by auction, but by tender for each lot or 'ticketing;' and experience has enabled the smelters to approach wonderfully close in their tenders for each particular lot. One of the great firms has been known to spend nearly half a million sterling in one year for copper ore, besides the machinery and the wages necessary to carry on the smelting. Of the smelting itself we need not speak in detail; it comprises sortings and siftings, calcinings and meltings, roastings and oxidisings, and other processes, by which all the sulphur and other substances are driven away, and the pure metallic copper alone is left. One notable curiosity in the manufacture is a very unacceptable one; it is the wreathing cloud of white smoke which hovers over each of the great smelting works, and which has gone far to spoil the once beautiful Swansea valley.

One of the most peculiar circumstances connected with *tin*, in the chemistry of its manufacture, is presented by what is called *tin-plate*. A tin kettle is *not* a tin kettle; if it were, its existence would be very evanescent; for tin will not bear the requisite heat. All tin goods of this kind are made of sheet iron, washed with liquid tin to shield them from rust and from chemical action. The thin sheet iron is cut into quadrangular sheets; these sheets are steeped in muriatic acid, heated in an oven, cooled, straightened and beaten smooth, drawn between rollers, steeped in bran-water, pickled in sulphuric acid, scoured with sand and water, washed in clean water, dipped in melted tallow, dipped in melted tin, drained till dry, and rubbed with bran—an extraordinarily complex series of operations, considering that the film of tin is after all so thin; but all are necessary to ensure an intimate junction of the two metals. South Wales claims to herself the credit of making the best tin-plates in the world.

The wonders of the iron manufacture have engaged a little attention in a former sheet of this work; but a few further notabilities occur to us in

respect to the *hot-blast*. This invention, simple as it may seem, has added almost incalculably to the wealth of our nation. Before this remarkable method was introduced, and when only *cold* air was blown into the iron furnaces, anthracite was too stubborn a kind of coal to be used conveniently as a fuel, and black-band iron-stone was too stubborn a kind of ore to be a favourite among the smelters; but now, when the blast is forced at a high temperature into the smelting furnace, the anthracite is found to yield intense heat, and the black-band to yield a rich percentage of good iron. The market value of the anthracite of South Wales and of the black-band of south Scotland must have been increased by millions sterling by the hot-blast alone. Well may Mr. Neilson be regarded as a public benefactor, by introducing it.

There are other examples in which a great revolution has taken place in one or other of the metal trades, owing to the application of some notable chemical discovery; though few so important in its results as that of the hot-blast. There are also a number of minor curiosities arising from the application of metal refuse to useful purposes. Brass-ashes, or the contents of a furnace in which copper and zinc have been melted to make brass, used to be deemed no better than common ashes and cinders; but it has recently been found that they contain enough of the mixed metals, which reach them in various ways, to give them a commercial value. The ashes become, in fact, a kind of substitute for copper ore, from which copper can be extricated by smelting. It is said that, scarcely a dozen years ago, brass-founders often paid money to have their ashes removed; but that now there are thirty thousand tons which can annually find a ready market, at ten to twenty shillings per ton. Even the slag which results from this smelting is useful; for it is in demand at Swansea to assist as a flux in smelting ordinary copper ore. The slag or dross of iron furnaces has, by the ingenuity of a French inventor, been made applicable to very useful purposes; by a careful process of casting or founding, this slag may be made into paving flags, large building blocks, and even pipes—of great hardness, polish, durability, and cheapness. Lead dross has a commercial value; it forms on the surface of lead while in process of melting; and by careful processes it is made to yield up nearly the whole of the metallic lead which had become combined with it. Type-founders' dross, in like manner, or the dross which forms on the surface of melted type metal, is made to yield up its metallic treasure by subsequent smelting. As to clippings, cuttings, raspings, filings, borings, turnings, sweepings, and other minor fragments of metal which form the refuse of manufactories, it is easy to see how they may be made available in the production of clean good metal.

Of gold a previous sheet has jotted down a few of the 'curiosities;' and we can here only say that the marvels of the 'diggings' in Australia continue to increase. *Two tons* of pure gold have been brought over in one ship.

There is a modern metal, or a metal of modern discovery, the chemistry of which is rendered remarkable by the unconquerable properties (if we may so speak) of the metal itself; this is *platinum*. It differs from all other metals in respect to the great difficulty with which it is brought into the ordinary metallic form. It is usually found, mixed with other rare metals, in grains or small pieces in sandy formations. To melt it into a mass is out of the question, on account of its extreme infusibility; and although it may be welded when softened by heat, yet the extreme slowness and difficulty of the process are such as to render the attempt almost hopeless. Had not Dr.

Wollaston discovered a better method, this invaluable metal would have remained almost valueless; for unless it can be brought into the form of a continuous sheet, crucibles and vessels could not be made from it. Wollaston showed how, by a particular mode of chemical treatment, platinum can be separated from the other constituents of the grains in the form of a fine black powder; how this powder, by the combined action of heat and intense pressure in steel moulds, can be condensed into a solid ingot or block; and how this block can be forged under a hammer to a proper degree of toughness and to any required degree of thinness. The great usefulness of this remarkable metal results from the obstinacy with which it resists nearly all external agents; heat, light, air, moisture, acids, alkalies—all alike are nearly powerless in respect to this refractory substance. Hence its importance in the fabrication of vessels for chemical purposes. Sulphuric-acid stills, crucibles, capsules, &c., are of great value when made of this material. At one time its price was almost fabulous. A manufacturing chemist in the north gave a thousand guineas for a sulphuric-acid still made of a thousand ounces of platinum.

## Chemistry of Paints and Colours.

It would be impossible to notice here more than a very small portion of the 'curiosities' which mark the chemistry of metals during the transformations incident to manufacturing processes. Sometimes the metallic or reguline state, sometimes the oxide or the chloride, sometimes the compounds with acids, present these remarkable aspects; and the treatises on chemistry are full of such examples. Our few instances above must be accepted as specimens; and the beautiful subject of the chemistry of *colours* will furnish us with a little further illustration.

The *zinc-paint*, now brought industriously before public notice, illustrates at once the ingenuity shown in devising means for remedying an evil, and the difficulty of applying the remedy in opposition to popular custom. White-lead is deleterious to health, and nothing has succeeded in rendering it otherwise. Hence attempts are being made to find a substitute; and zinc seems at present the best fitted for this office. The manufacture of the white oxide of zinc is a beautiful example of chemical action. Metallic zinc is heated in a furnace to which a current of air is admitted; the zinc vapourises; the vapour passes into a series of chambers; and here it collects on the walls as a light downy flocculent oxide, which is scraped off and removed. When ground up with linseed oil, the oxide forms a white paint, which may be the ground or substance for other colours used in house-painting. Then comes the rivalry between the two 'whites'—the oxide of zinc and the carbonate of lead. The chemical virtues of the former are insisted upon; but the advocates for the latter have not failed to point out qualities in which it is unquestionably the better of the two—especially in drying more quickly than the zinc-white, and having more 'body' or substance. One among many proposed modes of applying the zinc-white is in floor-cloth painting. In this manufacture, as every one knows, oil paint is laid on thickly, first with a brush and afterwards through the medium of carved blocks. The quantity of paint consumed is so large, that the white-lead contained in it becomes a sad enemy to the men employed in the processes; and hence a recent attempt has been made to adopt zinc-white as a substitute. At present the result is considered to be unsatisfactory in some respects; and we must therefore wait for better.

One thing at least seems undisputed, that zinc-white is less deleterious than white-lead.

This white-lead is ordinarily produced in a way still more remarkable than zinc-white. Let the reader picture to himself the following scene, and the actors in the scene. There is a large lofty room, with an earthen floor. On the floor is strewed a layer of ashes; on the ashes is placed a stratum of tanners' spent bark, two or three feet in thickness; on the bark are hundreds of earthen pots, placed closely side by side, and each containing about a pint of vinegar; on the earthen pots are layers, five or six in depth, of plates of lead, about an eighth of an inch in thickness; on the lead is a covering of boards; then other superposed series of tan, vinegar pots, lead, and boards—tan, vinegar pots, lead, and boards—and so on, until the mass is built up to a height of twenty feet or more. Women do the work; they cast the lead plates, they fill the vinegar pots, and they build up the curious structure—or it is at least true that, in the Newcastle district, where white-lead is made in immense quantity, more women than men are thus employed. The heterogeneous strata—often comprising ten thousand pots of vinegar and thirty tons of lead—being then closed in for several weeks, what ensues? The spent tan gives off heat; this heat evaporates the vinegar; the vinegar vapour acts upon the lead; and by a series of chemical actions the surface of the lead becomes changed into a white carbonate, which then constitutes white-lead.

This process is so tediously slow, that chemists are seeking around them for one more expeditious. Mr. Pattinson, of Newcastle, one of our leading manufacturing chemists, has succeeded in producing what he calls *oxichloride of lead*—manufactured directly from the mineral galena or sulphuret of lead, without all the parade of vinegar pots and tanners' bark; it is cheaper than white-lead; but its introduction has been too recent to determine its relative excellence as a colour-material. Ten thousand tons, or more than twenty million pounds, of white-lead are said to be produced annually in Great Britain; and there is thus great inducement to seek for new and improved processes. So enormous is the quantity of spent tan required for this singular operation, that the manufacture can only be carried on in the vicinity of tan-yards.

It is a most remarkable circumstance in respect to lead, that—dull and neutral as it is in its metallic state—it is the source whence many of our most brilliant colours are obtained. The carbonate of lead, or white-lead, is chiefly valuable as a groundwork for other pigments; but many of the other salts of this metal give to the painter some of his most lively tints. Take, for instance, the compounds of chromic acid with oxide of lead; these produce the beautiful yellow and red chromates of lead. Take, also, the compounds of bichromate of potash with lead; these yield the well-known chrome-yellow. If tell-tale chemistry speaks the truth, chrome-yellow takes part in the manufacture of our common mustards, being used to give the requisite yellow tint to the flour or oatmeal with which the mustard is said to be often plentifully mixed.

This relation between the metals and the colours used for painting is very intimate. Iron, for instance, is the source of many of the colours employed by the painter and the calico-printer. When the beautiful yellow prussiate of potash is combined with iron, there results the well-known Prussian blue, which is so largely employed by paper-makers and paper-hanging manufacturers. Then, again, if this Prussian blue be mixed with chrome-yellow, there is produced one among the many beautiful varieties of green.

But copper is, perhaps, a more prolific source of colouring materials than iron. The deadly arsenious acid forms with copper the brilliant Scheele's green, which—when used, as it often is, in painting sweetmeats and toys—is a dangerously poisonous enemy. When copper is combined with lime instead of arsenic, another tint of green is produced. The singularly veined carbonate of copper, lately rendered so familiar to us under the name of *malachite*, is sometimes ground to powder to form a useful but somewhat costly green colour for artists. But sulphate of copper, more popularly known by the name of *blue vitriol*, is one of the most beautiful and remarkable of these copper blues; the crystalline masses in which it is sometimes exhibited are indescribably splendid. Nor is its mode of production uninstructive or uninteresting. When a ship returns from a long course of voyaging, battered and worn, its copper sheathing is often found to be ill fitted to bear further wear; it is stripped off, and replaced with new. Among other purposes to which this old copper is applied is that of making blue vitriol; it is roasted in a furnace until it becomes converted into an oxide, and this oxide of copper is made to combine with sulphuric acid, and crystallise into the beautiful blue sulphate.

One of the most extraordinary metallic colours, however, in respect to the mode in which it is produced, is unquestionably *vermilion*. Chemistry presents few transformations more striking than this. If the reader were to submit to himself the question, what colour and what form of substance would result from melting together solid yellow brimstone and liquid white quicksilver, he would guess long before he hit upon the correct reply. The substance thus produced is the lovely red powder known to every one by the name of vermilion. How, when the melted sulphur combines with the heated mercury, change of state and change of colour ensue, is yet a mystery; chemists only know that such is the case—they cannot yet dive into corpuscular secrets.

The exquisite blue colour *ultramarine*—in respect both to its natural origin and to its factitious imitation—is one of the most interesting of colouring substances. The blue is intensely vivid, and possesses the valuable property of being almost unalterable by time—so much so, indeed, that when all the other colours of a picture have faded, the ultramarine blue remains as bright as ever, rather to the detriment of the harmony of colour in the picture. It is procured from a blue mineral called *lapis lazuli*, which is occasionally found as a vein in masses of granite in Bokhara and other countries. The stone is roasted by heat, and pounded to powder; it is then mixed with oil, wax, pitch, and other substances, and melted, which enables the colouring matter to separate from the other ingredients of the stone, and fall to the bottom. So rare is the mineral itself, and so difficult the process of preparation, that the exquisite blue ultramarine powder is often valued at its weight in gold—nay, there has lately been exhibited a specimen valued at twenty guineas per ounce.

That chemists and manufacturers should endeavour to imitate this costly pigment, is what might reasonably be expected. During the last twenty-four years Gmelin, Persoz, Robiquet, and others, have devised modes of producing very excellent substitutes for ultramarine; so cheaply, too, that a blue colour, more beautiful, intense, and brilliant than smalt, can now be obtained for fifteen pence per pound. This novelty is seriously affecting the smalt dealers of Saxony; for, by a clumsy anomaly in our customs tariff, smalt pays an import duty of 10*s*. per cwt., whereas ultramarine is admitted duty free.

The blue colour called *smalt* just adverted to, and of which little less than two million pounds are manufactured annually, has many interesting points connected with its production. Mr. Tomlinson, in a valuable paper read before the Society of Arts in 1851, remarked :—"I think I may safely affirm, that the blue colour which is so extensively used in painting and varnishing porcelain and earthenware, for tinging crystal, and for enamelling, for imitating opaque and transparent precious stones, for imparting a magnificent blue to glass, for giving a blue tint to writing-paper and to linen, for fresco-painting, for the blue figures which adorn paper-hangings—that the blue colour for these and for various other useful purposes in our arts and manufactures, is almost entirely obtained from two small districts, one in Saxony and the other in Norway."

The discovery of smalt, or rather of the *cobalt* from which it is made, was closely connected with the legends of mining. In the mountainous district on the confines of Saxony and Bohemia, there have for many ages been valuable silver-mines; and three or four centuries ago there was a belief in kobolds, or spirits, who protected the metallic riches of the mines. The silver ore became by degrees depreciated by the admixture of a brownish ore which no one could understand; it was thought the kobolds had spitefully converted the silver ore into this brownish rubbish; and the rubbish came by degrees to receive the name of the mischievous spirit himself. A glass-maker, however, on trying to melt some of this ore, found himself enabled by its means to impart a beautiful colour to glass; and from that day the much-despised kobold (or *cobalt* in modern orthography) became a valuable material.

The manufacture of smalt from cobalt is rather a complicated operation. The Swedish chemist Brandt found out that the mineral in its purest state is the oxide of a metal, to which he gave the name of cobalt. The ore, however, as met with in the mines, is a very complex affair; it contains not only cobalt, but also iron, nickel, bismuth, sulphur, and arsenic—all of which must be driven off before the beautiful blue colour can be obtained. The ore is stamped into fragments; it is plentifully washed with water; it is roasted for many hours in a reverberatory furnace, to get rid of many impurities; it is mixed with calcined quartz and purified potash; the mixture is melted in pots, in a furnace somewhat resembling that used by the glass-maker; the resulting melted compound is a blue glass, which is poured out in a white liquid state into cold water; the *smalt* thus produced is crushed, sifted, ground, washed, and otherwise reduced to a fine powder, which constitutes (according to its quality) the *azure* and *smalt* of the colour-dealer—varying in their delicate blue hues by almost imperceptible shades. The commonest kind of smalt is called *zaffre*. A part of the smalt used in this country is prepared at Birmingham; it is separated from the nickel with which the so-called 'German silver' is made, and is then sent to Staffordshire to be employed in painting porcelain.

In reference to artists' colours, modern chemical discoveries and inventions have enabled them to be produced at much cheaper prices than at any former period. The Society of Arts has recently put this question to the test. Wishing to aid in this matter, the Society offered a prize for the best box of water-colours which could be sold retail at one shilling—undertaking to purchase a certain number, to give a commercial start to the undertaking. The prize has been competed for and gained; and an excellent shilling box of colours is the result.

## The Chemistry of Dyeing and Calico-Printing.

Colour-chemistry has no more beautiful and important application than in the dyeing and printing of textile manufactures.

When a piece of cloth is dyed, does the colouring matter combine chemically with the filament, or does it simply lodge in little cells? Chemists and scientific dyers have long been discussing this question, but without arriving at undoubted results. All that seems to be known is, that if any one particular dye be applied to textile materials of cotton, flax, hemp, silk, wool, fur, or hair, it will adhere to them with different degrees of firmness, and will present different degrees of brilliancy, according to the nature of the filament. Whether there be an attraction or affinity (as chemists term it) between the filament and the dye, varying in strength in different instances; or whether the little cells or pores of the filament bear a certain relation in size to the dye particles—seems to be left for the determination of science at some future period.

But there is another source of diversity in the relations which dyes bear to the various filamentous substances above named. Whether it is that the cells of the filament and the particles of the dye do not suit each other in size without a little 'doctoring,' or whether principles of a more chemical character are at work, it is seldom that a piece of cloth will receive a dye without the intervention of some third material—some friendly agent which will adapt the other two to each other. All such agents are called by the dyer *mordants;* they have a 'biting' action (as the origin of the word shows); they bite the dye into the filament. Thus there arises a great diversity in mordants; for they depend not only on the nature of the dye which is to penetrate, but also on that of the filament which is to be penetrated.

But the chemistry of dyeing and calico-printing is far more complex than the 'mordants' seem to imply. There are no less than six different kinds of effect to be produced on woven cotton goods, by chemical means, before the dyeing and printing can be fully attained. One is the *cleaning*, the removal of all extraneous matters from the filaments; another is the *colouring*, or the imparting of actual tint to the cloth; a third is the *fixing*, or compulsory union of the dye with the cloth through the medium of a mordant; a fourth is the *discharging*, or the removal of colour from particular parts of the cloth by chemicals subsequently applied; a fifth is the *protecting*, or shielding the cloth from the action of particular colours at particular spots by a preparation called a 'resist;' and lastly, a sixth is the *brightening*, or the development of the beauty of the colours by an after application of certain chemicals. Now every one of these six effects has its own particular group of agents—its own range of chemical substances fitted to produce it—its own peculiar connection with the chemistry of colours; and it is scarcely too much to say that almost every discovery in chemistry is made available for one or other of the above six kinds of service.

To enumerate the crystals, the liquids, the powders, the gases thus employed, would take us a long journey through the range of acids, alkalies, salts, earths, and other bodies on which the attention of the chemist is bestowed. Sulphur assists in bleaching, and is the source whence the invaluable sulphuric acid is obtained; and this sulphuric acid is one of the means for obtaining the chlorine, the muriatic acid, and the soda, which enter so largely into dyeing and calico-printing. Common salt—the removal of

the duty from which has been an inestimable good to science and manufactures—is, however, the great storehouse for the last-named three substances; sulphur being an agent for developing them from this storehouse. Then, again, there are nitre and nitric acid, hot and biting, to act upon various substances which will not yield to less energetic acids. Then the metals copper, tin, iron, lead, &c.—when in the state of oxide—are most valuable adjuncts to the dyer's store. Again, the acids, when combined with the metals and earths and alkalies, give another series ever widening as chemistry advances. Add sulphuric acid to alumina, and we get alum; add it to iron, and we obtain copperas; add it to copper, and there results blue vitriol; add it to soda, and we produce Glauber's salt; add it to lime, and we obtain plaster of Paris; and so forth. It is not here meant, of course, to imply that if we place the two in contact, the compound named will be immediately produced; but that the compound is the result of the chemical union of those ingredients. Thus it is that, if such organic acids as the acetic, tartaric, or citric, or such mineral acids as the sulphuric, muriatic, or nitric, be made to act upon the oxides of the metals tin, lead, copper, iron, &c.; or upon the earths lime, alumina, &c.; or upon the alkalies soda, potash, or ammonia—there result compounds so numerous as quite to baffle any ordinary enumeration; and it is the duty and the interest of the dyer and the calico-printer to see which of these numerous bodies will be available to him in the production of colour in any one of the six different ways enumerated in the last paragraph. There really seems, therefore, something akin to the apparently inexhaustible powers of a permutation series in the double, triple, and quadruple compounds of chemical substances applicable to the dyer's art.

If we were to classify chemicals according to the dyes which they tend to produce, instead of according to their constituent ingredients, we should find strange companions grouped together. For a yellow colour we should find brilliant crystals obtained from horses' hoofs and blood, and known as prussiate of potash; chromate of potash; fustic wood; quercitron bark; weld and turmeric; and other vegetable substances. If it be red, we have a great variety of sources: there are the little bodies of the cochineal insect and of the lac insect; there are the vermilion and the lake series; and there are numerous mineral substances, such as the acetate of alumina. If it be blue, there are ultramarine and smalt, indigo and weld, and numerous other sources. And so might we glance one by one at all the colours: we should find that the three kingdoms of nature—animal, vegetable, and mineral—all contribute under singularly diverse forms. The colours denominated *lakes* form a curious group. They comprise animal or vegetable juices, rendered opaque and substantial by admixture with alum or some other mineral substance. Carmine, for instance—one of the most beautiful of colours—has for its organic element the little cochineal insect, which forms such an important article of commerce in Mexico. The vegetable substance called madder yields another and cheaper kind of carmine. Brazil-wood, by a peculiar mode of treatment, yields brown lake; while Persian berries, annatto, and quercitron bark are sources whence various kinds of yellow lake are derived.

Great is the array of tubs and vats, boilers and cisterns, employed by those who dye largely in the manufacturing districts; and great the ingenuity required to adapt the means to the end to be attained. Sometimes the cotton or the wool is dyed in the filamentous or unspun state; sometimes as a spun yard or thread; sometimes as a woven cloth. Silk is too fine and fragile to be dyed until after spinning. The chemistry of this dyeing is often very

deep and scientific. Let it be a blue colour which is to be given to cotton cloth, and indigo the dye material. Much management is necessary to fit the agent for the work it has to perform. It is first de-oxidised, to render it soluble, and to enable it to enter the little pores of the filament; and then it is re-oxidised, to fix it in its new home. During this process, it changes to a greenish-yellow colour; but this matters not, since the re-oxidation restores the blue. Chemistry has to entice the indigo to enter the little cells, and then entice it to stay there.

One most important difficulty of the dyer's art is to range all his colours into two groups—*substantive* and *adjective*—comprising those which adhere to the cloth by their own chemical energy, and those which will not constitute 'fast colours' without the aid of a mordant. Not only do dyes differ among themselves in this respect, but one particular dye has different habitudes in relation to different textile materials—cotton will often reject that which wool would receive kindly, and silk yet more kindly; and there has been much more thought and experimental research necessary to obtain brilliant and permanent dyes for cotton, than for silk or wool. In respect to the two designations used above, of substantive and adjective, we may adduce the colours called *lakes* as examples of adjective dyes, which cannot be fixed in the cloth without the aid of a mordant. Whether made from madder, cochineal, Brazil wood, saffron wood, logwood, quercitron, fustic, or weld; whether called red, crimson, purple, black, or yellow—all lakes seem to have this fugitive character, unless rendered substantive and fixed by the aid of a mordant.

Nothing can better illustrate the extraordinary complexity which sometimes marks the operations of the dyer, than the mode of producing the celebrated *Turkey red* dye—that which has been brought so much into favour by the bandana handkerchiefs. Here the brilliant tint is obtained by a long series of processes, each of which is intended to effect one particular change in the relation between the materials and the cloth. The cloth is steeped in an oily liquid; it is allowed to ferment or 'sweat' for several hours; it is exposed to the heat of a hot closet for several more hours; these three processes are repeated a second time, and then a third time; the cloth is steeped in an alkaline liquid; it is steeped in a solution of alum and galls; it is steeped in lime-water; it is boiled in a solution of madder; it is washed, cleaned, and dried; it is again steeped in alum and galls, and again boiled with madder; it is boiled for many hours with soap and pearlash; it is boiled a second and a third time, with some additional ingredients; it is exposed to the fresh air for some time; it is boiled in water containing bran; and finally it is dried. Now every one of these manifold processes is the result of laborious investigations, which have cost much time, anxiety, and capital, although the resulting product may perchance be sold very cheaply. The dyer knows that if he once obtains a reputation for a beautiful dye, it may avail him for a sale of millions of yards; and he therefore scruples not to devote his best attention to that which may make its appearance even in a cotton handkerchief sold for a few pence. The above-named processes for Turkey red are those adopted in France; the Lancashire and Glasgow dyers adopt various modifications in one or other of the manipulations. It is said that this rich tint owes more to the dyers than to the chemists; the dyers have discovered it by a series of attempts, while the chemists are yet at fault concerning the rationale of the several effects produced.

From the dyer to the calico-printer is but a step. Few persons at the present day, knowing to how extraordinary a degree the business of calico-print-

ing is carried on in the north, would suspect that it was first practised (so far as England is concerned) in and near London. At Richmond, at Merton, at Crayford, and a few other places, these processes were conducted before Lancashire had directed its energies to the subject; but it was not to be supposed that cheap labour, cheap steam, and the vicinity of the cotton manufacture, would do otherwise than attract the calico-printing operations towards that busy county. The founder of the now distinguished family of Peel may be considered the founder of Lancashire calico-printing. Whether 'Peel's parsley leaf' is yet in existence as a pattern for cotton dress goods, we do not know; but it would be a curious memento of the progress of the art; for some of the members of the first Sir Robert Peel's family are said to have perfected the first printed specimens of this pattern, with the aid of the domestic flat-iron, on the domestic ironing-board.

The higher class of printed goods at the present day comprises barège shawls, printed velvets, printed flannels, and the more costly varieties of printed muslins. Great artistic skill is shown in devising the designs, mechanical skill in preparing the blocks, chemical skill in selecting the colours, and manipulative skill in the printing. All the cheaper printed cottons are now printed by the cylinder-process. The pattern is engraved on the surface of a copper cylinder; and by an admirable adjustment of mechanism this cylinder feeds itself with colour, cleans itself from superfluous colour, draws in the cloth to be printed, and effects the printing. Every colour requires a separate cylinder; so that for the more complicated patterns the cylinder-machine is really a very fine example of engineering, irrespective of the beautiful chemical results which it aids in producing. But for the more costly and delicate goods, such as the shawls and velvets above noticed, the original block method is still adhered to. In this method each colour has a block for itself, on which a certain portion of the pattern is cut or engraved; and the blocks are used singly and by hand, each printing as much as its size and its colour will permit. Where the whole design is but a repetition of one small pattern, the whole surface of the cloth is printed by a succession of applications of the same two or three blocks; but where a large shawl (for example) displays a design which is *not* merely a repetition of small bits of pattern, the number of blocks often becomes multiplied in an extraordinary degree. One of the exquisite barège shawls recently produced is said to have required more than five hundred carved blocks to produce it, every one of which represents a different part of the device (either in colour or in pattern) from any of the others. It is the mode of weaving that gives to these shawls the title of barège; the material may be silk or wool, or a mixture of the two, or a mixture of either one with cotton—according to the price; but the printer's art has enabled him to impart beautiful printed designs to all the varieties.

## The Chemistry of Porcelain.

From the dyer and the calico-printer we will turn to the manufacturer of porcelain and pottery.

Nearly all nations have applied themselves, in a greater or less degree, to the potter's art. If we look to the tribes of central and western Africa, we there find rough and unglazed pottery, often baked in the sun; and such may also be said of semi-civilised nations all over the world. In India and Japan more neatness and ingenuity are displayed. In China, as is well

known, fine porcelain was produced centuries before anything of the kind was known in Europe. In southern Europe, the oil-jars and wine-jars are the chief varieties of native pottery, the higher kinds of earthenware and porcelain being derived from other countries. At Sèvres, Meissen, Berlin, Vienna, and Copenhagen, royal encouragement by the governments of France, Saxony, Prussia, Austria, and Denmark, has led to the formation of establishments in which enamelled and gilt porcelain is produced in great beauty and variety. Holland produces a homely delft or earthenware, fitted for the steady homely Hollanders. But it is in our own country that the greatest variety exhibits itself; from the exquisite porcelain, which we owe to the skill of the Copelands, Mintons, Chamberlains, and others, down to the coarse red flower-pot, every kind is produced in England; and in the middle portion of the series—that which comprises the cheap but well-made and neat white and blue-and-white earthenware—we confessedly take the lead of the world.

Strictly speaking, the chemistry of the potter's art is not very extensive; it is rather to a *mixture* than to a chemical combination of the ingredients that pottery is due. In the finer kinds, however, where the clay undergoes a kind of vitrification, a chemical change really takes place, for the substance becomes semi-transparent. The china clay, produced from granite, and forming the body of our porcelain; the china stone, also the result of the disintegration of granite, used for glazing porcelain; the clays necessary for producing white earthenware; and the commoner clays for the various sorts of brown and stone ware—all are met with in this country. The discovery of the proper materials for English porcelain was quite a curious episode in the history of the pottery art. The peculiar clay used in China for this purpose is called *kaolin;* M. D'Entrecolles, who visited China in the last century, sent home a few specimens of this kaolin; and Mr. Cookworthy, of Plymouth, found on examination that it was identical with a very fine clay which he had seen near Helston, in Cornwall. It was nearly a century ago that this discovery was made; and from that day the English porcelain manufacture may date its commencement—though many struggles had to be borne before success attended the enterprise. This fine china clay differs from other clays chiefly in having a percentage of the very rare earth called *lithia;* all alike contain about two-thirds of their weight of *silica* or flint. At St. Austle and other parts of Cornwall, in the summer months, busy operations are being carried on, by which the quartz and mica are washed out of the clay (they having formed part of the granite which by disintegration constitutes Cornish clay), and the pure kaolin or porcelain clay is left behind. It is supposed that at the present time not less than twenty thousand tons of clay are annually shipped from Devon and Cornwall to the pottery districts—so enormous is the manufacture of porcelain. It must be borne in mind, however, that the clay is not *all* so employed; there is much demand for it by the paper-makers and the calico-printers, who employ it as a stiffening material—perchance to make things appear better than they really are. These statements relate to the carefully-prepared clay for fine porcelain; a much greater weight of commoner clay is sent from those two counties to the Staffordshire potteries.

One of the most pleasing advancements in the potter's art is that which has led to the production of the beautiful statuettes now so extensively known. It is not wholly a modern phase of the art, but within the last few years it has reached its highest degree of excellence. The great

firm of Messrs. Copeland was, we believe, the first to introduce, about 1842, that delicate variety of porcelain to which the name of *Parian* is given; and from that time may be dated what we will call the *sculpturesque* period of English pottery. Some call the material Parian, some call it Carrara; but be it called what it may, it very successfully imitates the more delicate kinds of marble employed in statuary. Gods and goddesses, nymphs and graces, satyrs, heroes, vases, urns—all are produced in this material, generally in miniature dimensions. The names of some of our best sculptors are now to be seen associated with graceful productions in this material—mind infused into clay. We must not, however, estimate this branch of art too highly. It is not really more sculpturesque in the mode of production than humbler departments of the art. The sculptor supplies a model; the moulder is very careful in preparing a mould from this model; the ingredients are combined with more than usual care; and the casting, baking, and subsequent processes are all sedulously attended to; but still it is not less a manufacture, in its details, than the production of plates and cups and dishes. Of the ingredients of this Parian nearly two-thirds are silica or flint, about one-third is alumina or clay, and the small remainder is made up of minute portions of soda, potash, lime, magnesia, and iron. All that careful pounding, calcining, grinding, sifting, mixing, boiling, evaporating, and kneading can do, to bring these ingredients into a perfectly fine and smooth state, is done, and all that the moulder's skill can effect is duly brought to bear on the perfection of the moulds. The Parian is not used in the state of clay, but as a liquid, analogous to the state in which plaster of Paris is employed in making casts. The creamy mixture is poured into the mould; some of it solidifies, and the rest is poured off; the solidified portion is baked until it assumes a firmness of texture; the mould is taken to pieces and the cast liberated; and all crudities of surface are removed.

But this is only a part, and the less artistic part, of what is to be done; formidable difficulties yet remain. A 'Dorothea' or an 'Ariadne' cannot be extricated whole from one single mould; the head, the limbs, the drapery, have so many curves and undulations of form, that only a small part can be yielded by one mould. Some of the groups recently produced have required as many as fifty moulds. Then comes the difficulty—the building up of a graceful form from many moulded fragments; the Parian artist is the Frankenstein of his art. The pieces have to be cemented together, and the joinings so obliterated that their existence can hardly be traced. There is a further source of embarrassment; the drying of the Parian makes it shrink to a remarkable degree; and unless great nicety be observed in the proportions of the several parts, and in the drying processes, the portions may not fit well together when all are ready. A 'Venus' with one leg shorter than the other, or the 'Graces' with crooked shoulders, or a 'Una' too big for the lion on which she is seated, might be awkward results of any failure of accuracy in these particulars. And it is not merely in putting these pieces together that great care is required; but also in the subsequent drying and firing. Let the goddess be ever so well shaped when her component limbs are set in their places, yet the slightest want of caution in adjusting it in the annealing oven may occasion a twist or bend which would render her a deformed goddess from that moment.

Such, then, is the mode in which the beautiful Parian statuettes are produced. Within the last few months a large number of such productions have met the public view, illustrating the talents of Bell, Gibson, Marochetti,

Danneker, Westmacott, Cellini, Foley, Thorneycroft, Canova, Townshend, Power, Marshall, &c., on the one hand; and those of Minton, Copeland, Chamberlain, Rose, Wedgwood, Ridgway, &c., on the other.

The terra-cottas, another example of the application of pottery to fine-art purposes, are decidedly more clay-like in their character; they make no pretensions to the porcelain-like texture of Parian; but yet they are susceptible of very wide application. The clays are carefully selected, the moulds are wrought by a man of taste, the mixing and pressing are effected with judgment, and the firing is also well managed; the resulting terra-cotta ('baked clay') then becomes a very advantageous decorative material for the architect's use. The entire external ornaments of a church near Bolton are made of terra-cotta.

And what is said of terra-cotta may be said nearly as much of the now-important manufacture of encaustic tiles or tesselated pavements. The clays are selected with care, and all the manufacturing processes are sedulously managed. There are two additional features here—that the material is used partly as a clay to be *pressed* into moulds, and partly as a cream to be *poured* into moulds; and that the materials have brilliant colours imparted to them by the admixture of metallic oxides.

There is perhaps more chemistry in the glazing, the painting, and the gilding of the potter's productions than in the earlier stages of manufacture. The glazing is truly a coating of glass; and the problem has been to discover a mixture which, if applied as a liquid, may be baked into the state of a solid glass. Salt and lead are known to be two of the ingredients employed; but manufacturers have others which they wish to keep secret, each for himself. Be the ingredients what they may, they are made into a liquid, in which the cup or other article is dipped; and the heat of a 'glaze-oven' converts this liquid into the beautiful and durable glassy envelope with which we are so familiar on our table-ware. In the painting and gilding of the more costly specimens, nearly all the colours employed are metallic oxides, mixed to the proper consistency with turpentine and various kinds of oils and spirits. When applied to the ware, these colours appear dull and dingy; but the heat of the 'enamel-kiln' not only burns the colours indelibly into the ware, but developes very brilliant tints. Great is the attention necessary in this firing; for if the degree of heat and the length of its continuance be either more or less than a due medium, the colour fails in its development, and perhaps also fails in its due fixity. The porcelain-painter and the glass-stainer are equally dependent on the chemistry of heated metallic colours.

The chemistry of cement is a curious one; for the stony particles adhere with a force which is in some instances almost equal to the power of stone itself. The so-called Roman cement has long been famous for its cohesive property; but the Portland cement recently introduced far excels it. In an experiment lately conducted, two solid blocks were prepared, one of Roman and the other of Portland cement; and they were placed in such positions that weights might be suspended from them. The Roman cement yielded to a disruptive force of eleven hundred pounds, but the Portland cement stoutly maintained its integrity till rent asunder by a weight of nineteen hundred. But this cement has still more strikingly shown its strength when used as a mortar in brickwork. On a recent occasion, in Hyde Park, a brick beam was built up with Portland cement as a mortar. The bricks were hollow, and were so ranged as to form a beam about four feet in height by two in width. This beam was rested at the two ends on supports more than twenty feet

asunder, and weights were suspended from the centre; and not until the astonishing weight of nearly seventy thousand pounds was thus applied did the beam yield and break. It was not the actual binding power of the cement alone that resisted this enormous force, for thin slips of iron were introduced at different parts; but the experiment was intended to show how much strength might be obtained by hollow bricks and Portland cement, aided by a little iron.

The production of 'artificial stone,' now employed for many building and decorative purposes, has in it something of a more chemical character than that of cement; for flint is actually dissolved to enable it to combine with other substances.

## What we owe to our Salt-Mines and Alum-Pits.

The chemistry of our invaluable salt district is not so noteworthy for the processes by which the salt is brought into marketable form, as for those which the salt itself subserves in the manufacture of chemicals and drugs. Yet is the Cheshire routine of operations very interesting. Beneath the valleys of the Weaver and its tributary streams are those vast saline treasures which seem as if they would be inexhaustible. There are near Northwich two beds of hard dirty-looking rock salt, one at a depth of about three hundred feet, and one much nearer the surface; the beds are very little less than a hundred feet in thickness, and have each an area of about a square mile. The contents, therefore, of the Northwich beds can be approximately calculated. There are nearly twenty mines there, from which the salt is obtained by a series of operations nearly analogous to those of coal-mining, and in quantity amounting to sixty or seventy thousand tons annually. But this is not the salt with which we are familiar; it is nearly all exported. Our well-known and precious table-salt is obtained almost entirely from brine-springs, which form in unknown quantities beneath the ground, by water flowing over salt-beds of unknown dimensions. Pumps, well applied, never fail to draw up this strongly saline liquor; it is pumped by steam-engines into vast reservoirs, from which pipes convey it to shallow iron evaporating pans, where heat causes the water to evaporate and the salt to crystallise. There are evaporating houses in Cheshire which exceed even the Crystal Palace in length, and in which a thousand tons of salt can be produced in a week. These brine-springs yield prodigious quantities; it is said that the Cheshire produce has now reached nearly half a million tons annually.

In tracing the manufacturing uses of salt, we may observe that it is really little less than impossible to follow out correctly the steps by which valuable chemicals result from the production of other chemicals. Almost all chemical transformations result from a play of affinities. A will combine with B, but it has a still stronger liking for C; while B has a more energetic affinity for D than for A: if these four elements get together, they busily readjust their connections; their former states of combination will very probably be overthrown, and we shall have two resultant compounds, AC and BD. Among many chains of processes, let us take one particular chain as exhibited in the great chemical works of the north, in connection with the use of salt, and see how curious are the gradual developments of new compounds.

We begin with sulphur—the crude yellow brimstone which is brought in such large quantities from Sicily, and is also one of the residual products of our copper-smelting works. It is put into a furnace and burnt away—form-

ing sulphurous acid gas by its combination with the oxygen of the atmosphere. The gas is collected in leaden chambers, some of which are so vast as to have a capacity of a hundred thousand cubic feet; and in these chambers it is made to combine with a little more oxygen and then with water, whence results liquid sulphuric acid—the well-known but strangely-named oil of vitriol. This hot burning acid, produced from tasteless sulphur and salubrious oxygen, is heated in a furnace with common salt; and one of the consequences is that muriatic acid gas is driven out of the salt. This acid, mixed with water, and allowed to trickle upon common chalk, will produce carbonic acid gas in great abundance—either for making soda-water or for any other purposes. Muriatic acid, too, if heated carefully in a stone vessel with oxide of manganese, gives up its chlorine in the form of a gas; and this chlorine, if admitted to a chamber in which slaked lime is placed upon shelves, converts this lime into chloride of lime or *bleaching powder*—a substance which has created quite a revolution in bleaching and dyeing processes.

But we must now go back to the point at which the muriatic acid was separated from the salt. The sulphuric acid cannot drive the muriatic acid out of the salt without being itself brought within the range of affinities; the granular salt becomes a pasty sulphate of soda. A little coal and a little chalk are added, and another action of affinities commences, which settles down into the production of carbonate of soda and sulphuret of calcium. Carbonate of soda is that invaluable form of soda which is now used to so enormous an extent in glass-making, soap-making, bleaching, washing, and other operations. When another dose of carbonic acid gas is given to this carbonate of soda, it becomes bi-carbonate, the nice-looking white powder which forms an essential ingredient in soda-water and ginger-beer powders.

Thus, then, we see how extraordinary is the production of valuable chemicals from the decomposition and recomposition of some of the cheapest and most familiar of substances. Brimstone, salt, coal, chalk—nothing very beautiful or costly about them; and yet with a little aid from other substances, we find them yielding sulphuric acid, muriatic acid, carbonic acid, chlorine, bleaching-powder, soda-water powder, and carbonate of soda. There is one thing which chemistry has not yet done in the matter, but which it must do before this beautiful train of processes can be considered complete; it must discover some use for an earthy substance called sulphuret of calcium. In the production of the carbonate of soda, although sulphuric acid and chalk are required as agents, to bring about changes by the play of affinities, yet the sulphur of the one and the calcium of the other form no component parts of the carbonate of soda itself, the resultant of the process; they constitute a solid refuse which is a sad burden to the manufacturers. This refuse or waste is sulphuret of calcium; no means have yet been devised of making it profitably available; it cannot be ignored; it must not be thrown into rivers or canals; it is a 'great fact,' which has necessitated the purchase of acres upon acres of land, upon which the refuse is thrown up in huge heaps as high as a moderate house, and with a bulk of many hundred thousand cubic feet. When we find that every fraction of the refuse from gas-works has been rendered serviceable for some purpose or other, we must not doubt that chemistry will by-and-by do something with these monster heaps at the soda factories.

As salt has its chemical notabilities, so has *alum*. In truth, the chemistry of this substance has not a little that is remarkable about it. The three very

dissimilar substances—sulphuric acid, clay, and potash—combine to form it: and when so combined, its scientific name becomes 'sulphate of alumina and potash.' For many ages it was produced chiefly from a particular kind of earth or ore; but modern ingenuity has devised a mode of preparing it by a direct union of the materials. Let us briefly glance at both methods.

In many countries there are strata of alum-stone or alum-slate, which will yield alum by proper treatment. There is a thin layer of alum-stone between layers of coal and lime; and when the coal has been removed by mining, the alum-stone becomes gradually so acted upon by the atmosphere as to become disintegrated and powdery. But whether stony or powdery it is all brought up to the surface, as it contains sulphuric acid and alumina—two of the ingredients for alum. The stony portion is made to yield to fire, instead of air and moisture; it is built up into huge pyramidal heaps, and there fired until brought to a state of disintegration. Then do the processes of steeping and boiling and crystallising take away from the alum that which it does not want (iron), and impart to it that which it needs (potash); the potash being added just before the crystallisation. The alum-maker obtains an additional product, too, beyond his alum; for the iron which forms part of the alum-stone he contrives to separate, and to convert into beautiful green crystals of copperas —so surely does any complicated chemical process lead to the production of substances besides that which is the immediate object in view.

But the Newcastle chemists have devised a mode of making alum independently of the aid of alum-stone. Give them sulphuric acid, clay, and potash, and they will return you a mass of crystalline alum as the resulting product—not among the least of the curiosities of chemistry. Cornish clay, calcined and ground very carefully, is mixed with sulphuric acid; the two boil up together furiously, without any heat being applied (another of the 'curiosities'); water is added; and after a time for subsidence, the liquid is pumped into another vessel, where potash is added to it. Crystallising, and steaming, and re-crystallising then convert this liquid into a solid mass of alum—ready for any of the purposes which it is fitted to subserve in the arts. When the crystallisation takes place in a very large vessel, and the staves of the vessel are pulled asunder to liberate the solidified alum (a frequent practice) the appearance of the huge mass is really magnificent, especially if we look at the brilliant radiating crystals in the interior cavity. One of the many striking results of these combinations shows itself in this manufacture. Alum is the product sought for, but *Prussian blue* is also obtained in immense quantity; the clay employed contains some iron, which must be got rid of in some way or other; and it is finally driven out in that form which constitutes the beautiful Prussian blue.

It is one of the grand feats of chemistry that—every now and then—it gives commercial value to materials hitherto useless: converts into a boon that which has been a burden. There is an example in point, connected with our present subject. Around our numerous collieries are huge heaps of a slaty substance called *shale*, which forms the material of the interlying beds between the seams of coal; it is removed when the coal is mined, and is a perpetual source of annoyance to the coal-owners, who do not know where to put it or what to do with it. How great would be the advantage, then, of any project which might bring this shale into use! So thought Mr. Spence, of Manchester, who formed a plan, about seven years ago, for producing alum from the shale; he adds one annoying refuse (gas-works' waste liquor) to another annoying refuse (shale from coal-mines), and from the two, by various

chemical processes, he produces alum, copperas, and sulphuric acid. M. Robin exhibits few marvels more 'mystérieuses' than those which chemistry often achieves; and what is more to the purpose, these chemical marvels have a most potent influence on the well-being of the world in general.

Another interesting fact in connection with the recent manufacturing history of alum is, that dyers and calico-printers are now beginning to use only the *essential* parts of it, rejecting those which have no mordant quality. Alum is a sulphate of alumina, with one or other of the three alkalies, potash, soda, or ammonia; but chemists now know that the alkali simply causes the alum to crystallise, without adding to its mordant power. The dyers say, "we care not about the crystalline structure, give us the mordant;" and forthwith the manufacturing chemists of Newcastle devised a way to produce slabs or blocks of opaque sulphate of alumina, which—though neither crystalline nor beautiful—have all the potency for which alum is valued.

## The Chemistry of Fermented Drinks.

There is perhaps no department of manufacturing chemistry marked by more interesting circumstances than that which comprises the production of fermented liquids. The wonders of organic chemistry are many, and some of them are made manifest in this department. Different as we may consider the general vegetable structure of corn, sugar-cane, fruit, beet-root, and potato, they may all be employed as sources whence to obtain alcohol or spirit; different as are spirit, beer, vinegar, and quartern loaves, they may all be obtained from the same corn; and different as are wine, beer, cider, malt, sugar, and molasses, vinegar may be obtained from any or all of them.

It is a curious stage in the chemistry of this subject, that *sugar* must be developed before any of the fermented drinks can be produced; indeed, sugar is the substance which undergoes the fermentation.

In the first place, then, sugar is a very abundant component part of vegetable substances. It is found in the sugar-cane, in the maple, in beet-root, in carrots and turnips, in potatoes and parsneps, in grapes and fruits of all kinds, in manna, in liquorice, in mushrooms, in every kind of grain—indeed it is one of the most generally diffused of vegetable principles. Practically, the sugar-cane is the source whence the sugar of commerce is most readily obtained. How the canes grow in tropical countries; how the 'slave-question' is mixed up with everything relating to the commerce in these canes; how the canes are cut when ripe—these are questions which precede what we may term the chemistry of the subject. The canes are rich in juice, a sweet but crude liquid; this is expressed from them by the crushing force of ponderous rollers, and trickles into a cistern beneath. Then, to prevent an acidifying process, the juice is at once boiled rapidly, the impurities removed from the surface, the watery portion evaporated, and the rest brought to the state of a thick syrup. A hundred average sugar-canes will yield about five gallons of juice, from which six pounds of crystallised sugar result. The syrup is cooled in shallow vessels, and then packed in hogsheads. The drainings or molasses from the syrup are fermented to yield rum, and the granulated sugar in the hogsheads forms our 'moist' or 'brown' sugar. Then, when brought to England, the sugar is either sold in the imported state, or is chemically treated to form 'white' sugar. In the latter case it has to pass through strange ordeals. Melted in hot water, strained through canvas bags to get rid of the impurities, filtered through pounded charcoal to dissipate colour,

boiled *in vacuo* to drive off much of the water, granulated to prepare for crystallisation, crystallised to separate the treacle—all these are processes through which the sugar must pass in its transformation from brown 'moist' to white 'lump,' and in which many curious processes are involved.

One of the novelties in this sugar-chemistry is connected with beet-root. Sugar has been prepared from this useful vegetable for many years past in France and Germany; and hopes are now entertained respecting it as a panacea for poor Ireland. A hundred and fifty thousand tons of beet-root sugar are now said to be made annually on the Continent; and as Ireland grows the beet favourably, an attempt is being made to establish this manufacture there. A factory has been built at Mountmellick, in Queen's County, with a subsidiary establishment for cutting and drying the beet. The factory can operate on 300 tons of beet per week, supposing a supply to be obtainable. The roots are gathered, cut, topped and tailed, washed, and rasped into pulp; the pulp is pressed to yield the juice; the juice is boiled, purified with lime-water, evaporated, boiled *in vacuo*, and crystallised. Perhaps we may yet see the day when the beet-root will benefit the sister island.

As sugar exists in so many vegetables, so must there be sugar in all the substances which yield fermented drinks; and the mode of compelling this sugar to render up its properties is full of chemical niceties.

Let us see what results when beer or ale, porter or stout, is to be produced. Any kind of corn will yield beer; because the starch contained in a grain of corn is convertible into sugar, and the sugar into a fermentable substance. But by the process of *malting* (in which moisture and heat are applied to barley) the starch of the grain is converted into sugar in such a state as greatly to facilitate the brewing process. Malt, therefore, or malted grain, is employed by our brewers. The malt is crushed between steel rollers to a powder, or rather grist (we are speaking of the operations at the great porter breweries); it is mashed with hot water to extract the saccharine matter from it; the extract is boiled in huge coppers with the flowers of the hop, to impart bitterness; the extract or 'wort' is cooled, then fermented in vessels of an enormous size, then 'worked' or deprived of its frothy yeast, and then fined or cleared. The chemistry of brewing is placed in an interesting light by the recent declaration of the Burton ale-brewers (made under circumstances which enforce belief), that the high-class Burton ale is made from no other ingredients whatever than malt, hops, and pure water.

But the spirit or alcohol of the distiller is more chemically important than the ale or beer of the brewer; since it passes through more advanced stages of progress. Brandy is produced from wine, rum from molasses, whiskey and gin from corn; they are all alike, however, in owing their fundamental quality to the alcohol which they contain. Each country employs the saccharine material most readily obtained; and thus the flavour of different kinds of alcoholic beverage depends on local circumstances of soil and climate. The wine-regions of France have in the grape an abundant supply of sweet juice which yields spirit by distillation; the sugar-planters of the West Indies have a thick sweet residue from their sugar-drainings which is rich in alcoholic elements; and corn-growing countries have in store the starchy supplies which become transformed first into sugar and then into spirit. The *differences* between brandy, rum, and whiskey depend on the differences between grapes, sugar-canes, and corn; the *resemblances* depend on the alcohol which they are all in common capable of yielding.

So far as our own English-made spirits are concerned, they can be pro-

cured either from raw grain or from malted grain, Some distillers employ malt only, but as this is very costly, raw grain is usually employed in larger quantity—barley, chiefly; but also wheat, rye, and oats; it is a question of £. *s.* *d.* with the distiller, at any particular time and place, to combine his ingredients according to the state of the market. These ingredients, then, are regularly *brewed* before they can be distilled; the saccharine matter must be extracted and fermented before alcohol can be obtained. The malt is crushed, the grain is ground, the water is heated, and all three are mashed up together in a mash-tun; the sickly-sweet extract or 'wort' that results is cooled and then fermented, by which the sugar of the grain becomes converted into alcohol. To separate this alcohol from the water is the object of distilling; the fermented liquor or 'wash' is boiled in close stills; and the alcohol, becoming vaporised sooner than water, passes out of the still in a vaporic form, and is then condensed into liquid spirit by the vicinity of cold water. Real good whiskey is much more scientifically pure (so to speak) than any kind of gin or cordials; the latter are 'doctored' in various mysterious and questionable ways.

As spirit is an advance upon beer, so is vinegar an advance upon spirit, in respect to the chemical history of the liquid produced. It may be made from any of the substances which will produce beer, or from any which will produce spirit, or from beer and spirit themselves; but it goes one stage beyond them in the chemistry of its manufacture. Various sources are employed by different vinegar makers, but malt is more generally used by the manufacturers in the neighbourhood of the metropolis. It would be a sore complaint to make against the usquebaugh of Ireland, or the 'mountain-dew' of the Highlands, that it was sour or acid; and yet these burning liquids are produced from the very same kind of malt as the greater part of the London vinegar. The vinegar-maker grinds his malt into grist; he extracts 'wort' from this grist by mashing; he cools the wort in a refrigerator; he ferments the wort into *gyle* (a distiller would call the liquor *wash*, while to a brewer it would be simply unfinished *beer* or *ale*); he transfers the gyle into casks; and he there causes it to undergo the acetous fermentation which converts it into vinegar. This acetous change is very remarkable, for it may be brought about either by the heat of a closed room or by the fresh air of a field. In France the stoving is most practised, and it is gradually becoming extended in England; since the field-method, by leaving the liquid many weeks or even months in the casks, renders much capital unproductive throughout this period.

In all these processes—in the extraction of juice from the sugar-cane, in the preparation of brown sugar from the juice, in the refining of this brown sugar into white, in the production of beer and ale, in the distillation of the various kinds of spirit, in the making of vinegar—the recent improvements have been so many and varied, that we cannot even enumerate them. The niceties of chemistry have, one by one, been rendered available, either for the improvement of the liquid produced, or for the economy of the materials employed.

Wine-making has also its chemistry, though not to so notable an extent as the examples just adduced. Take the case of ordinary sherry, for instance. The fine Spanish grapes are gathered in September, when fully ripe; they are sorted, turned, and exposed to the sun for a couple of days; they are placed in a shallow trough, and are jumped upon in an uncouth manner by men wearing wooden shoes. The bruised grapes are subjected to the action

of a wooden press, by which the *must* or juice is pressed out; and this must, received into proper vessels, is allowed to ferment into wine. The great point of difference between wine and the other fermented drinks is, that the former gains very greatly in quality by keeping; the fermented juice contains many more substances than merely alcohol and sugar; and these substances acquire by age many attributes which the connoisseur knows well how to appreciate. Why 'fine old crusted port, twenty years in bottle,' is different from new port, vegetable chemistry must tell us. Wine-making is not a steam-engine process; it is an old-fashioned operation of old-fashioned countries, and is but little subject to change or improvement.

## Chemical Miscellanies.

We will group together a number of miscellaneous examples which present curious or novel aspects.

The boracic acid lagoons of Tuscany afford a notable example of a dreary desolating natural phenomenon being made available to man's use by the aid of chemistry. In a mountainous district about twenty miles from Sienna there is a fearful region. Bare and bleak mountains are immersed in clouds of thick sulphurous vapour; boiling hot water bursts from the ground with explosive noise, giving off abundance of smoke and vapour; miniature eruptions frequently occur in the ground, producing dismal hollow reverberating noises; the heat is close and suffocating; the surface of the ground is covered with much crystalline and efflorescent matter; and there are lagoons or ponds containing liquid of such a dread character that no living thing can bear immersion in it for an instant. The water of these lagoons has been found by modern chemists to contain boracic acid; and hence it became an object to try whether the useful substance *borax* could thence be obtained. The quantity of the acid in the water is not large; but it is known that the vapours which curl about the mountains include boracic acid vapour; and a happy mode has been suggested of making these vapours useful instead of deleterious to mankind. Artificial cavities are formed at various heights in the mountains, which become gradually filled with water by the mountain streams; the hot vapours which burst from the ground, in the beds of these cavities, combine with the water, and convert it into a kind of weak boracic acid; and this acid, by concentration and crystallisation, produces borax. It is awful work, however: an accidental fall into one of the lagoons is almost certain death.

Nothing can be more curious and instructive, in connection with manufactures, than the contrast between the sources whence chemical substances are obtained, and the purposes to which those same substances are appropriated. Acids, alkalies, salts—all exhibit these contrasts. We have noticed many such examples; let us glance at a few more.

Let *tartaric acid* be an instance. This acid is obtained from the 'tartar' (as it is familiarly called) which is deposited in wine-vats during fermentation, and which is subjected to melting and crystallising and other processes to make it yield up the acid. Many thousand tons are procured annually from France, Spain, Italy, and other wine-producing countries; and when the beautiful acid crystals are derived by chemical aid from the tartar, they are employed in calico-printing, and in the preparation of lemonade and other cooling beverages. White wines and red wines yield two different kinds of tartar, similarly designated as white and red; and according to the mode of

treatment, in the manufactories near London, either *cream of tartar* or *tartaric acid* is produced from the crude tartar. Another acid, the *citric*, is obtained from lemons, and is applied to numerous purposes, including some nearly identical to those for which tartaric acid is fitted. The concentrated juice of the fruit is subjected to various crystallising and other processes.

Oxalic acid, gallic acid, benzoic acid—all are crystalline, and all are obtained from animal or vegetable substances. It seems strange to those unfamiliar with chemistry that such a substance as oxalic acid—crystalline in form and poisonous in quality—should be derived from such heterogeneous sources as sugar, silk, saw-dust, hair, and glue—substances notably unlike each other. The fact is, however, that there are certain chemical elements in each of them which may be separated by various processes, and made so to recombine as to form oxalic acid; for this acid consists of nothing but oxygen, carbon, and water. The sorrel which school-boys pick in the fields derives its sourness from the presence of this acid. In manufactures and various processes it has something of a bleaching action; for it is used by calico-printers for 'discharging' colours from cloth; and it is also employed for whitening boot-tops, straw bonnets, and other articles. Gallic acid, another of the three mentioned above, is prepared from nut-galls; it forms a chief ingredient in writing-ink, which in part owes its blackness to this acid. Benzoic acid is produced from a gum or resin called benzoin—or, in more popular language, *benjamin;* it is the juice of a tree growing in tropical climates, and has a very agreeable fragrance.

There are many other acids employed in manufactures or in medicine, the sources of which are very remarkable. Thus the much-dreaded *arsenic*, or arsenious acid, is derived largely from the tin-mines of Cornwall; the metal arsenic is combined with most ores of tin, and in the process of roasting the ore the arsenic is separated in the form of arsenious acid or white arsenic.

Nor are the salts less worthy of attention in respect to the sources whence they are obtained. These salts are generally compounds of acids with alkalies, earths, or metallic oxides. Take the muriate of ammonia, or sal-ammoniac, as an example. The first information which chemists had respecting this salt was that it came from Egypt. It is well known that the sandy districts of that country are very deficient in fuel; the inhabitants have to tax their ingenuity to find a substitute; and one such substitute is dried camels' dung, which gives a dull smouldering kind of fire. The soot or 'blacks' which rises from this fuel is found to contain much muriate of ammonia; and means are adopted for extricating this salt from the soot. These means, as adopted by the Egyptians, are singularly rude and primitive, and were not likely to maintain ground (so far as the supply of Europe is concerned) after chemistry made its recent gigantic strides. Ammonia, in one or other of its combinations, is now known to be present in a number of animal substances, such as silk, hair, and wool—bone, blood, and flesh—horn, hoof, and claws; and the carcases of slaughtered animals supply an abundance of such substances at a very cheap rate. Modern chemistry is the most universal and the most useful of all scavengers; it collects refuse from every possible quarter, and extracts value and beauty from it. A horse's hoof, or an ox horn, is quite a treasure to the chemist; he will utterly destroy it so far as form and component structure are concerned; but look at the glittering crystals, and the brilliant colours, and the useful acids and salts, which he will obtain by the transformation. The gas-works, too, which are obliged to use liquids to wash and purify the gas, would be burthened with an

unsavoury ammoniacal liquor, were it not that the chemist kindly steps in and uses this liquor as a source whence to obtain sal-ammoniac.

The nitre which forms such a notable ingredient in gunpowder is another of those salts which occur in queer and out-of-the-way places. That the walls of stables and cellars, the sides of caverns, and the surface of the ground in hot climates, should yield nitre in a fine powdery state seems somewhat strange; yet such is the case, and a large portion of the commercial supply is thus obtained. In some of the tropical regions of Africa and Asia nitre forms on the ground as a white efflorescence, when heavy rains have been succeeded by intense heat: the rain first acts on certain constituents of the soil, and the heat then developes the nitre as a chemical resultant. The natives scrape off an inch or two in depth of the soil, steep it in water so as to wash out the nitre, allow the earthy matter to subside, expose the nitreous liquor in shallow vessels to the heat of the sun, and evaporate it so as to produce crude coarse nitre. In other countries of the East the nitre is scraped annually from the walls of caverns, and treated nearly in a similar way.

Like as in the case of sal-ammoniac, so in the present case, modern chemistry has found the means of producing the compound from sources independent of any particular localities. A little nitre is contained in tobacco, maize, beet-root, and other plants, but not in sufficient quantity for manufacturing purposes. By making, however, a sort of artificial nitre-ground, or a bed containing nitreous materials, the formation of nitre is ensured at any convenient spot. Stable dung, vegetable mould, wood ashes, and other substances which contain either nitrogen or potash, are worked up into a sort of clay and built into beds or heaps, the slow action on which by the atmosphere leads ultimately to the production of nitrate of potash, the chemical name for nitre.

The bones that used to be thrown away, unless sufficiently large and good for the purposes of the turner, are now sedulously preserved. Either the mill grinds them up into a powder for manure, or the chemist extracts phosphorus and other valuable matters from them. The soot and sweepings and sewage, which used so to perplex our forefathers, and which still perplex those who have been slow to avail themselves of modern discoveries, are precious stores to the chemist, whence he obtains products often of singular beauty and usefulness. Blood, lime, charcoal, and other substances used in the refining of sugar, were formerly consigned to the dust-heap or the common sewer when the refining was completed. Not so now, however; for the additions they have acquired in the process render them actually more valuable to the chemist than in their former pure state. Twenty years ago guano was utterly without value in the market; but agricultural chemistry has now given it such a value that hundreds of ships are employed in conveying it across the seas. The gas companies used to pay money for permission to throw away their refuse ammoniacal liquor into the common sewers; but chemistry, as we have just remarked, has created a profitable market for this liquid. The water in which fleeces are washed becomes impregnated with the greasy impurities with which the wool filaments are coated, and this water used to be thrown into ditches or drains; but now, by adding a little alkali to it, a kind of soap is produced which is available in the subsequent scouring operations in the woollen manufacture.

The chemical history of *congreves* or *lucifers* is by no means devoid of interest. The days of the flint and steel are passed, so far as England is con-

cerned; a tinder-box will become a curiosity in a few old-fashioned houses. The first attempts of chemistry in the matter were rather showy and laboured. There was the French method of obtaining light by means of the heat developed in compressed air, the compression being produced by a piston in a tube; there was the phosphorus bottle, and the sulphur match to act upon the phosphorus; there was the sulphuric acid bottle, with matches tipped with chlorate of potash; there was the platina bottle, with a complicated apparatus for producing and directing a stream of hydrogen gas on the platina. But all these have given way to the modern congreve—the very perfection of simplicity and usefulness and cheapness. Whether the composition with which the matches are tipped be one or another of the various mixtures now known to chemists, and whether they ignite noisily like lucifers or quietly like congreves, they all alike have the property of ignition simply by friction. All the matches have either phosphorus or chlorate of potash as one ingredient in the composition with which they are tipped. Of the splints or matches themselves we have said a few words in the sheet relating to Wood; and we may here add, that a witness, examined a few years ago before the Children's Employment Commissioners, stated that he used a thousand pounds' worth of American pine yearly in the making of lucifer-boxes. He stated his belief that from twelve to fifteen thousand gross were made every week in London; and as each box contains about fifty matches, the yearly produce of matches in London would thus amount to five thousand millions.

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